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WEPTASK RRMA 05 078/200 1/F012 16 003
EVALUATION OF HIGH-VISIBILITY,
COLOR SCHEMES FOR AIRBORNE VEHICLES

Aircraft Detectability and Visibility:
VI. A Qualitative Review and Analysis of the
Utility of Fluorescent Paint for
Increasing Aircraft Detectability and Conspicuity

NAEC-ACEL-492 4 MARCH 1963

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This report was prepared by Applied Psychological Services, Wayne, Pa., in fulfillment of NAVAIRMATCEN Contract N156-38581.

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AIRCRAFT DETECTABILITY AND VISIBILITY

VI. A Qualitative Review and Analysis of the Utility of Fluorescent Paint for Increasing Aircraft Detectability and Conspicuity

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for the

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ABSTRACT

Both pilot opinion and recent basic and applied studies of fluorescent paint are considered. The pilot opinion sampled supported the use of fluorescent paint for increasing aircraft conspicuity and detectability. Although not all the basic and applied studies of fluorescent paint reviewed indicated self-consistent findings, the use of fluorescent paint for increasing aircraft conspicuity and detectability also seemed indicated by these studies. A series of recommendations on fluorescent paint application is presented.

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CHAPTER I

INTRODUCTORY CONSIDERATIONS AND PURPOSE

As part of a continuing program aimed at the development of measures to increase or reduce the visual detectability of Naval aircraft, Applied Psychological Services, in collaboration with the Air Crew Equipment Laboratory, U.S. Naval Air Material Center, has been conducting laboratory and field studies into the relative visibility of fluorescent and ordinary paints. The present report considers pilot attitudes toward the efficacy of current fluorescent paint schemes in operational situations and summarizes earlier research on fluorescent paint application of this and other programs. Additionally, a suggestion, based on current knowledge and experience, is made for a paint scheme which may be optimally conspicuous.

Nature of the Operational Problem

The records of mid-air collisions involving military aircraft indicate that the majority have occurred during straight and level flight, under VFR operating conditions, while in or near an airport control zone. Baker (1960) cites statistics on the 634 mid-air collisions involving Air Force aircraft in the eighteen month period from January 1947 to June 1948. Baker's statistics suggested that:

1. approximately 80% of the mid-air collisions occurred during daylight, VFR conditions

2. most collisions occurred within 20 miles of an airport.

Similarly, the U.S. Naval Aviation Safety Center has required reports of all near mid-air collisions for some years. Examination of the data based on the reports for the periods January 1959 through July 1959 and January 1960 through January 1962 indicates again that the typical incident occurred during straight and level flight, under VFR conditions, at altitudes under 10,000 feet and when the visibility was in excess of 5 miles.

A summary of these data is presented in Table 1.

Table 1

Summary of 317 Near Mid-Air Collisions

Factor	Number	Percent
Aircraft Involved		
Military and military	130	41
Military and civilian	137	43
Military and unknown	50	16
Type of Aircraft Reporting		
Single engine	177	56
Multi engine	140	44
Time of Day		
Daylight	222	70
Twilight (incl. dawn)	23	7
Night	71	22
Unknown	1	1
Altitude (thousands of feet)		
0 - 1	8	3
1 - 5	128	40
6 - 10	109	34
11 - 20	24	8
21 - 30	29	9
31 +	19	6

Table 1 (con't)

Factor	Number	Percent
Type of Clearance		
IFR	109	34
IFR/VFR on top	20	6
VFR local	150	48
VFR cross country	31	10
Other (incl. combination and unknown)	7	2
Visibility (miles)		
0 - ½	13	4
½ - 1	2	1
1 - 3	12	4
3 - 5	31	10
5 - 15	139	44
15 +	117	37
Miss Distance (feet)		
0 - 100	57	18
100 - 1000	203	64
1000 +	42	13
Unknown	15	5
Sighting Distance (feet)		
0 - 100	28	9
100 - 500	98	31
500 +	171	54
After passage	10	3
Unknown	10	3

Proximity Alerting and Warning Systems

Electronic proximity warning systems may, in the future, serve as a means for reducing mid-air collisions. In view of the obvious need for preventing mid-air collisions, it seems that any reasonable avenue for increasing the detectability of intruding aircraft should not be overlooked. The probability of an in-flight collision is necessarily positively correlated with the degree of congestion of the air-space. This congestion is increasing and will undoubtedly continue to increase.

According to Klass (1962), recent engineering developments have suggested the feasibility of infra-red based proximity warning indicators. These devices are of two natures. The simpler serve to alert the pilot to the presence of an intruding aircraft. The more complex would not only alert the pilot to the threat but also compute and indicate the escape maneuver. It seems, however, that proximity warning indicators may neither represent an immediate solution to the mid-air collision problem nor an ultimate panacea. It is important to understand that, as Baker (1960) has implied, until suitable instrumentation has been developed, the primary detection responsibility must remain with the pilot. The simpler devices merely alert the pilot to the presence of the hazard. The pilot must then visually identify the intruder(s) and initiate evasive action. Hence, the need for optimally detectable and maximally conspicuous exterior coloration schemes still exists. Size, weight, cost, and maintenance penalties may serve to make the more complex alerting and warning systems unrealistic for certain private flight and military applications.

Furthermore, the addition of still another cautionary indicator requirement to the already overloaded cautionary and warning information requirements of modern aircraft presents problems which must be carefully evaluated. Can it be expected that the addition of another warning indicator will produce effective warning results? Brown and Siegel (1956) indicated, as the result of a survey of Naval operational aircraft, an average of 17.1 warning and cautionary light indicators for jet aircraft and an average of 13.1 for propeller-driven aircraft. Thus the question of whether the effectiveness of a proximity warning indicator will be watered down by the presence of a large number of other warning and cautionary indicators remains open.

If the proximity warning device is to be of an auditory nature, will the warning signal interfere with radio and ground control communications? Obviously such a sound must be so loud and intrusive that it cannot be ignored.

The near miss data cited above suggest that the proximity warning device will be most active in those areas in which tower communications most frequently occur.

It is not the purpose here to defend or offend proximity warning systems. It is suggested, however, that in the immediate future visual identification of intruding aircraft will be required and that means to augment aircraft conspicuity and detectability might represent an important contribution to reduction of the mid-air collision problem.

In spite of the human limitations for purposes of detecting and avoiding high performance aircraft and the obvious need for better instrumentation to assist the pilot, the human observer is still of paramount importance. Any measure which can decrease the detection time by even a fraction of a second may mean the difference between a collision and a near-miss.

Purpose of this Report

In order to gain greater insight into pilots' opinion of their need for collision avoidance information, a series of interviews was completed with Naval pilots having diversified flight experience. The present report presents the results of these interviews. Second, the present report attempts to integrate recent studies into aircraft detectability and conspicuity and to suggest an aircraft exterior coloration scheme for achieving this purpose. The scheme suggested is considered tentative rather than definitive; it should be compared in carefully formulated research with the current Naval pattern and other suggested schemes (e.g., the FAA supported pattern) and with practical considerations before it is supported for flight use.

CHAPTER II

PILOT INFORMATION REQUIREMENTS

A field interview of the semi-structured nature was designed in order to obtain an indication of pilot attitudes and opinions in the field of reducing mid-air collisions by visual means. A second purpose of the interview was to obtain additional actuarial data on in-flight near collisions and to explore the reactions of pilots to the uses and accomplishments of fluorescent paint application.

Sample

The sample of 96 pilots was intended to be as heterogeneous as possible. It was expected that the type of mission on which a pilot's squadron was usually deployed might influence, to an extent, his attitudes toward the questions involved. The sample consisted of pilots in operational Naval helicopter, attack, utility, and patrol squadrons and a reserve squadron. The reserve group was within itself quite heterogeneous. Virtually all types of operational Naval aircraft are flown by the operational squadrons represented (HU-2, HU-4, VA-42, VA-43, VU-4, VP-24) and the reserve group at the Naval Air Station, Willow Grove, Pennsylvania.

A description of the distribution of the sample is presented as Tables 2, 3, and 4.

Interview Development and Content

The interview content was jointly derived by members of the Air Crew Equipment Laboratory, Naval Air Material Center, and members of the professional staff of Applied Psychological Services. After initial development, the interview questions were pre-tested on a sample group, revised, and set in final form. This final interview schedule is presented as Appendix A to this report.

Table 2

Distribution of Sample by Squadron

Squadron	N
HU-2, HU-4	21
VA-42, VA-43	22
VU-4	10
VP-24	10
Willow Grove Reserve	33

Table 3

Distribution of Sample by Rank

Rank	N
ENSIGN	1
LTJG	21
LT	39
LCDR	23
CDR	12

Table 4

Distribution of Sample by Total Flying Time

Hours	N
0-999	16
1000-1999	35
2000-2999	13
3000-3999	17
4000-4999	8
5000-5999	1
6000-6999	1
7000-7999	1
8000-8999	1

13000-13999	1
not reported	2

The interview proper inquired into a number of areas. Question 1 was concerned with whether or not the pilot had ever experienced a near in-flight collision during daylight and the conditions of the incident. By conditions was meant altitude, visibility, relative speeds, activity (other preoccupation at time), flight phase, sun position, sky background, aircraft types involved, type of clearance, time of day, relative flight paths, first sighting distance, miss distance, exterior coloration of aircraft involved, and whether or not the pilot being interviewed was wearing sun glasses at the time of the incident.

Since an intruding aircraft will be viewed against different background hues and brightness, as the flight phase varies, and since the merit of an exterior coloration scheme will vary with sky background conditions, an exterior coloration scheme which is best for one condition may not be best for other conditions. Accordingly, question 2 inquired into the phases of flight in which the pilot feels it more important to determine quickly the presence of an intruding aircraft. The following comparisons were made:

a. airport control area and
b. cruise

a. take-off and climb-out and
b. landing

a. holding pattern and
b. cruise

a. below 10, 000 feet
b. between 10, 000 and 20, 000 feet
c. over 20, 000 feet

After each comparison, the pilot interviewed was asked to justify his answer.

Question 3 inquired into the alternative use of color for identity coding purposes rather than for increasing detectability, and question 4 asked whether the pilot being interviewed considered aircraft conspicuity more or less important than aircraft detectability. Justification for answers to these questions was also called for from each interviewee.

Items 5 and 6 asked whether a coloration scheme which indicated the relative altitude, flight path, or distance of an intruding aircraft would be preferable, even if it meant the loss of distance detectability. As before, the respondent was asked to justify his answer.

The final series of questions (items 7, 8, 9, and 10) probed specifically into the use of fluorescent paint for detectability purposes. General reactions (item 7), specific instances in which it has helped to detect the presence of an aircraft which might otherwise have not been seen (item 8), instances in which it has hindered, distracted, or given wrong or distorted information, and changes of impression after experience with fluorescent paint were sought (items 9 and 10).

Interview Procedure

Each interview consumed approximately 20-30 minutes. Although the topics were covered and the specific questions were asked, as in the interview form, no attempt was made to limit an individual pilot's discursiveness. It was assumed that useful information, overlooked in the design of the interview, might thereby come to light. If a pilot's responses seemed incomplete or overly terse, further remarks were elicited through probing statements.

As nearly as possible, responses were recorded verbatim. Some of these have been included in latter sections of this report, to exemplify the summaries reported.

Nearly all of the pilots seemed highly motivated to contribute any information they possessed to this obviously vital area. The interest of all those who participated in furthering any contribution to flight safety was reflected in a general spirit of cooperation throughout the field survey.

Near Miss Results

The first interview question was designed to obtain information which might supplement near miss data such as that presented in Table 1 and to ascertain some of the conditions existing during any daylight, near in-flight collisions which the pilots might have experienced.

Very few (10%) of those questioned were unable or unwilling to remember and discuss at least one near miss. In the words of one of the pilots who was asked if he had ever had a near miss, "Sure, any pilot who says he hasn't is a liar."

A summary of the conditions under which near accidents reported occurred is presented in Table 5.

With a few preliminary qualifications it is possible to compare the data in Table 5 with the results of the Naval Aviation Safety Center reports summarized in Table 1. First, it must be noted that the present interviews were concerned with the effectiveness of fluorescent paints, and thus asked for information on daylight near misses only. With one exception, therefore, all of the present interviews were reports of daylight incidents. Second, the NASC data are derived from spontaneous reports, that is, the only incidents included are those in which the pilot was sufficiently concerned to file a report. The present incidents include those which the pilots did not think sufficiently serious to warrant report, and incidents which occurred at various times in the past so that the details may not have been as vividly recalled.

With these qualifications in mind, it may be noted that the data in Table 5 show a higher percentage of incidents involving two military aircraft than the NASC data. Further, a higher proportion of the present incidents involved reporting pilots who were flying single engine aircraft. This latter may be attributed to two factors: (1) the relatively small proportion of the total sample who were currently in multi engine squadrons, viz., the ten members of VP-24 and a few of the Willow Grove reservists and (2) the number of lookouts, cited earlier, aboard patrol aircraft.

Eighty-three per cent of the reported near misses occurred below 10,000 feet; 62 per cent occurred below 5,000 feet. The comparable figures for the NASC data are 77 and 43 per cent respectively. Although many pilots also reported that they are busier with instruments at lower altitudes and have less time to scan for other aircraft, this finding may simply be an artifact of the greater density of traffic in these altitude ranges.

Seventy-two per cent of the present group of incidents occurred under VFR conditions, as compared with the NASC figure of 58 per cent. This difference is probably due to the sample differences pointed out above.

Table 5

Summary of Data on 86 Reported Near Mid-Air Collisions

Factor	Number	Percent
Sky Background		
Clear	38	44
Hazy	27	31
Cloudy	15	17
Overcast	1	1
Ground	1	1
Night	1	1
Unknown	3	4
Aircraft Involved		
Military and military	58	67
Military and civilian	24	28
Military and unknown	4	5
Aircraft Reporting		
Single engine	78	91
Multi engine	7	8
Unknown	1	1
Clearance		
VFR	72	84
IFR	12	14
Other	2	2

Table 5 (con't)

Factor	Number	Percent
Activity		
None	40	46
Instruments	19	22
Controls	12	14
Search	11	13
Other	4	5
Altitude (thousands of feet)		
0 - 1	13	15
1 - 5	41	47
6 - 10	17	20
11 - 20	7	8
21 - 30	3	4
31 +	5	6
Sun Position (with respect to flight path)		
0°	7	8
45°	6	7
90°	7	8
135°	12	14
180°	8	9
225°	3	4
270°	9	10
315°	10	12
Unknown	24	28
Visibility (miles)		
0 - 4	14	16
5 - 9	14	16
10 +	58	67

Table 5 (con't)

Factor	Number	Percent
Relative Speed (nauts)		
1 - 100	12	14
100 - 150	8	9
150 - 200	7	8
200 - 300	18	21
300 - 500	19	22
500 +	19	22
Unknown	3	4
Operations Phase		
Take-off	1	1
Climb	10	12
Cruise	44	51
Hold	3	4
Turn	2	2
Descend	5	6
Land	9	10
Aerobatics	2	2
Other	10	12
Sight Distance (feet)		
0 - 100	7	8
100 - 500	23	27
500 +	48	56
When past	7	8
Unknown	1	1
Miss Distance (feet)		
0 - 100	33	38
100 - 500	27	31
500 +	25	29
Unknown	1	1

Table 5 (con't)

Factor	Number	Percent
Collision Course		
Head on	19	22
Overtaking	29	34
Crossing	36	42
Unknown	2	2
High vis. Markings		
One	26	32
Both	11	14
Neither	44	54
Sun Glasses or Visor		
Yes	30	35
No	47	55
Unknown	9	10
Time of Day		
7 - 9	2	2
9 - 11	17	20
11 - 13	20	24
13 - 15	20	24
15 - 17	14	17
17 - 19	10	12
19 - 21	0	0
21 - 23	1	1

The angle of convergence between the two aircraft involved was sufficiently variable in both studies as to preclude drawing any conclusions as to a particularly dangerous quarter.

The operations phase during which the reported incidents occurred reveals again that more than half of the near misses occurred during straight and level flight.

The present data show also that the great majority (83 per cent) of the near misses reported occurred when the visibility was greater than five miles. The NASC figure was 81 per cent.

The distance at which the intruding aircraft was first seen is very nearly comparable for the two samples. Fifty-six per cent of the present group reported sighting the intruder at greater than 500 feet. The NASC figure was 54 per cent.

Some of the data obtained from item 1 was unique to this study and has no counterpart in the NASC reports. Pilots in the present sample were found in most cases to be occupied solely in flying the aircraft without abnormal distractions. The time of day at which the reported near misses occurred seems to vary normally throughout the daylight hours. Of the 86 pilots reporting near misses, 26 said that only one plane possessed fluorescent markings, 11 that both planes were so marked and 44 that neither plane was marked.

It was conjectured that the filtering effect of sunglasses and visors may add to the potential for accidents. Thirty pilots reported that they were wearing some visual light filtering device at the time of the incident; 47 were not.

To summarize, the near miss data reported suggest that time of day, position of the sun, visibility and angle of convergence had little differential influence on the sample of near misses obtained. Moreover, the findings of this survey agree, by-and-large, with the data of the Naval Aviation Safety Center and with the results of an Air Force analysis of real collisions cited by Baker (1960). Thus it may be tentatively assumed that near misses occur under conditions similar to actual collisions.

So far as generalities may be drawn it seems that the typical daylight collision may be expected under near optimum visual conditions, below 10,000 feet, in an airport control area or during level flight.

Need for Quick Detection by Flight Phase

Item 2 of the interview inquired into those flight phases in which the pilots regarded it most important to quickly determine the presence of an intruding aircraft. First the airport control area and cruise phase were compared. The results are presented in Table 6 and indicate that 62 per cent of the total chose the airport control area over the cruise phase.

The most frequent reasons given for considering the airport control area the more important were the density of traffic and the additional press of business inside the cockpit during this phase.

Those (28 per cent) who considered cruise a more important phase for visual detection did so mainly because of the lack of ground control and the overconfidence generated by a comparatively low traffic density.

The few (6 per cent) who would not specify usually considered that it was always important to be alert for intruding aircraft.

The second aspect of item 2 called for a comparison of take-off and climb-out with landing. The results of this comparison are presented as Table 7.

In commenting on the relative importance of take-off and climb-out as opposed to landing, 57 per cent of those stating a preference chose the take-off and climb-out condition as more critical. Reasons for the take-off choice included the limited field of view in the take-off configuration, limited maneuverability, and relative lack of ground control. Those choosing the landing configuration as more critical said that during this flight phase more traffic is funneling into a small area and that they are more occupied with controls and instruments. Some of this group also listed limited visibility as a factor in their choice. Evidently the problem of attitude yielding less visibility depends to some extent on the type of aircraft involved.

Table 6

Responses to Item: "In Your Experience Have You Found it More Important to Quickly Determine the Presence of an Intruding Aircraft in . . . . ?"

Squadron Type	Airport Control Area		Cruise		No Difference	
	N	%	N	%	N	%
Helicopter	12	57	6	29	3	14
Reserve	25	76	7	21	1	3
Attack	11	50	10	45	1	5
Utility	7	70	3	30	0	0
Patrol	7	70	2	20	1	10
TOTAL	62	65	28	29	6	6

Table 7

Responses to Item: "In Your Experience Have You Found it More Important to Quickly Determine the Presence of an Intruding Aircraft During ..... ?"

Squadron Type	Take-Off and Climb-Out		Landing		No Difference	
	N	%	N	%	N	%
Helicopter	9	43	6	29	6	29
Reserve	19	58	12	36	2	6
Attack	11	50	9	41	2	9
Utility	4	40	6	60	0	0
Patrol	4	40	2	20	4	20
TOTAL	47	49	35	36	14	9

As indicated in Table 8, when the pilots were asked to compare cruise with a holding pattern (third comparison of item 2) opinion was about evenly divided. Fifty-six per cent of those with a preference chose the cruise phase as more important. The question, as put, was evidently somewhat ambiguous. Responses indicated a difference of opinion as to how much ground control is exercised in a holding pattern. Whatever the choice, though, the reasons given reflect primarily the factors of overconfidence, lack of attention to scanning, and overreliance on ground control to assure separation.

The relatively higher closing speeds in cruise were also cited as giving less time to avoid a collision. One interesting reason for choosing cruise was, "in holding you are on gauges anyway and you shouldn't be looking around."

Finally item 2 inquired into the critical altitude range. The results are presented in Table 9.

The choice of a critical altitude seems to have been predicated mainly on the type of flight in which the pilot is involved. Many of the pilots had little experience above 10, 000 feet; accordingly they chose the range of altitude up to 10, 000 feet as more critical or did not express a choice because of their limited experience.

Other pilots who thought altitudes below 10, 000 feet to be most critical often cited traffic density as their reason.

Only five per cent thought the intermediate altitudes (10, 000-20, 000 feet) most critical.

Those who considered the over 20, 000 feet altitude range as more critical most commonly gave the reason that closing speeds are higher and aircraft response time is slower at these altitudes.

To some extent the divergence of opinion elicited by this question seems to depend on the type of aircraft flown. Pilots of high performance aircraft regarded the higher altitudes as most important while those without high altitude experience answered in terms of their most usual flight altitude range.

Table 8

Responses to Item: "In Your Experience Have You Found it More Important to Quickly Determine the Presence of an Intruding Aircraft . . . . ?"

Squadron Type	In a Holding Pattern		During Cruise		No Difference	
	N	%	N	%	N	%
Helicopter	6	29	12	57	3	14
Reserve	16	48	16	48	1	3
Attack	7	32	12	55	3	14
Utility	4	40	6	60	0	0
Patrol	5	50	3	30	2	20
TOTAL	38	40	49	51	13	9

Table 9

Responses to Item: "In Your Experience Have You Found it More Important to Quickly Determine the Presence of an Intruding Aircraft . . . . ?"

Squadron Type	Below 10, 000 ft.		Between 10, 000 and 20, 000 ft.		Over 20, 000 ft.		No Difference or No Experience	
	N	%	N	%	N	%	N	%
Helicopter	11	52	0	0	5	24	5	24
Reserve	23	70	3	9	5	15	2	6
Attack	9	41	1	5	9	41	3	14
Utility	4	40	0	0	5	50	1	10
Patrol	7	70	1	10	0	0	2	20
TOTAL	54	56	5	5	24	25	13	14

Color Coding or Detectability

Item 3 of the interview was concerned with the use of color on aircraft exteriors for identification (coding) purposes as opposed to the use of color for increasing aircraft detectability and conspicuity.

Virtually all of the pilots questioned (98 per cent) considered overall distance detectability to be more important than any coding system. Typical of the responses was the remark, "I really don't give a damn what it is, just where it is?", or "you could care less what kind of cotton picking airplane it is."

Detectability versus Conspicuity

Two different aspects of the problem of increasing aircraft visibility are the issues of detectability and conspicuity. By detectability is meant the maximum distance at which an object can be seen (object threshold). Conspicuity refers to visual attention intrusion properties of an object within detection range. Chromatic objects generally first appear achromatic as a result of atmospheric attenuation. As the distance between the target object and observer decreases, the object takes on its predominent hue. Research has suggested that certain paints may lower the absolute distance at which an aircraft may be first seen. However, aircraft coated with these paints will, through color contrast, be quite conspicuious when they appear. Other paints possess greater distance detectability but become apparent as colors at distances which are shorter than the first mentioned coatings. In order to gain some insight into which of these types of exterior coatings might be preferred, the pilots were asked whether they would prefer to detect an intruding aircraft early but with less visual intrusion as opposed to later but with more visual impact when it became apparent (item 4).

In answer to this question, almost all (96 per cent) of the respondents emphasized the importance of maximizing distance detectability in order to allow time for appropriate evasive action.

Accessory Flight Information Through Paint Schemes

The next portion of the interview attempted to elicit attitudes toward the use of exterior paint schemes to provide information beyond the simple presence of other aircraft. It is apparent that any such coding of the exterior could result in loss of overall distance detectability.

Item 5 asked whether the pilot would prefer, even at the loss of distance detectability, visual information on altitude (item 5a), relative flight path (item 5b), and relative distance (item 5c) through appropriate painting,

Item 6, which was included as a check on the responses to item 5, asked, "Which if any of the following codings do you think you would like to see incorporated into aircraft paint schemes, relative speed, relative altitude, relative direction, and relative distance?"

The responses to item 5, as summarized in Table 10 suggest that the pilots sampled were of the opinion that anything which increases distance detectability is desirable and that once detection has been achieved the pilots considered themselves capable of taking the appropriate evasive action. This statement tends to be supported by the fact that in several of the near mid-air collisions reported, the pilot was unaware of the presence of the other aircraft until it had passed him. There are obvious limitations to this thesis. With high performance aircraft it is possible that a collision will occur even when each pilot observes the other plane at the limit of visual detectability. In the head-on condition and at a closing speed of 1,200 mph, it has been estimated that the pilots must see each other at around a distance of 9,500 feet in order to avoid a collision.

Opinion Concerning Fluorescent Paint

Since fluorescent paint has been attributed with a potential for increasing aircraft conspicuity and detectability, a series of questions pertaining to pilot opinion of fluorescent paint was included in the interview.

Item 7 asked the general question, "I suppose that you have seen fluorescent paints such as this around airports and in flight. What do you think of it?" The percentage of responses, as categorized along a strong like--strong dislike continuum, are presented in Table 11.

Over 90 per cent of the pilots were strongly or mildly positive in their reaction to fluorescent paint. Typical of the positive reactions were:

Table 10

Responses to Item: "Would You Prefer —— Even at the Expense of Distance Detectability?

Squadron Type	Visual information on relative altitude				A paint scheme which told you relative flight path of the intruder				A paint scheme which told you relative distance			
	Yes		No		Yes		No		Yes		No	
	N	%	N	%	N	%	N	%	N	%	N	%
Helicopter	0	5	21	95	3	14	18	86	1	5	20	95
Reserve	4	12	29	88	6	18	27	82	5	15	28	85
Attack	1	5	21	95	2	9	20	91	1	5	21	95
Utility	2	20	8	80	2	20	8	80	1	10	9	90
Patrol	1	10	9	90	2	20	8	80	1	10	9	90
TOTAL	8	8	88	92	15	16	81	84	9	9	87	91

Table 11

Pilot Opinion of Fluorescent Paint

Squadron Type	Strongly Negative		Mildly Negative		Neutral		Mildly Positive		Strongly Positive	
	N	%	N	%	N	%	N	%	N	%
Helicopter	0	0	1	5	0	0	14	67	6	29
Reserve	0	0	0	0	1	3	25	76	7	21
Attack	0	0	1	5	0	0	14	64	7	32
Utility	1	10	2	20	2	20	5	50	0	0
Patrol	0	0	1	10	1	10	5	50	3	30
TOTAL	1	1	5	5	4	4	63	66	23	25

"they do stand out, particularly through haze."
"great for visually acquiring these aircraft."
"highly ideal--very effective--considerable improvement.
"extremely effective."
"real fine--they really show up--increase of objects--brighter."
"outstanding."
"fine for sighting things for safety purposes--they do facilitate detection at high altitudes."
"it gives a feeling of security in case you go down."

Typical of the negative reactions were:

"they wear out rapidly."
"they look lousy..."
"...don't think they do an awful lot of good."
"very hard on eyes out in the sunshine."
"better than nothing, but not too effective, what is needed is luminescent paint that could be detected under adverse lighting conditions."

The usual response to the follow-up item, "What do you like best about it?" was "...its detectability."

The most frequently mentioned disliked characteristics of fluorescent paint were its purported lack of durability and the difficulty of applying it, especially under adverse conditions such as those found aboard a carrier.

Item 8 approached the utility of fluorescent paint head on. Seventy-six of the 96 pilots sampled replied affirmatively to the question, "Can you think of any situation in which it has helped you to detect the presence of an aircraft which you might not have seen otherwise?"

The follow-up question for those who answered affirmatively was, "Tell me how the fluorescent paint helped?" Typical responses were:

"contrast with background--birds aren't this color."
"by alerting you..."

"over coast--when you are coming in. Today there was a plane with none on and following him was a Navy plane with fluorescent paint scheme and you could really see him."

"... it gives a better silhouette."

"... we did have planes with and without it and planes with it were always easier to detect."

"... at first glance the fluorescent caught my eye."

"... just like a bell out there."

Item 9 asked the obverse question, "Can you think of any situation in which it has hindered you, distracted you, or has given you wrong or distorted information?" Here 89 of the 96 pilots queried replied "no." Typical of the elaborations given by those seven who replied "yes" was a vague feeling of discomfort and interference with depth perception when flying formation on a bright day. In at least one case it was claimed that this miscueing was eliminated by the use of a visor.

Change of Impression Over Time

Finally the group was asked (item 10) whether their impression of the usefulness of fluorescent paint for aircraft detectability purposes has changed from when they first became aware of its usefulness for this purpose. Of the group of 96, 71 replied "no" and 25 replied "yes." A tabulation of the direction of the change for those who replied "yes" is presented in Table 12.

Table 12

Direction of Change of Impression of Fluorescent Paint Over Time

	N	%
Increased Favorableness	16	64
Decreased	8	32
No Response	1	4

Discussion

While pilot opinion of the value of fluorescent paint for increasing aircraft conspicuity and detectability and research data on the extent, if any, to which fluorescent paint achieves this purpose may differ, pilot opinion does represent one aspect of a complete evaluative armamentarium.

The pilots almost universally agreed as to the general utility of fluorescent paints in increasing aircraft detectability and conspicuity. Most could cite instances in which they considered the use of fluorescent paint to have helped them detect other aircraft which they might not have seen otherwise.

Few had any objections to the use of fluorescent materials beyond the difficulties of maintenance and the fact that certain operational missions require low conspicuity.

Typically the more experience a pilot had with high visibility paint schemes, the more he accepted their use. Reserve and helicopter squadrons, where the high visibility paint is generally mandatory, were slightly more favorably inclined. However, in operational squadrons requiring low visibility for avoidance of detection, there was little contention as to the effectiveness of fluorescent materials, only on their utility for the combat mission.

A few of the younger pilots tended to associate the use of high visibility paint schemes with the training command and indicated that such associations might tend to lower the feeling tone related to the paint.

The pilots indicated little desire to receive accessory information through exterior coating. Maximum detectability was desired. After having seen an intruding aircraft, the pilots maintained that they could plan and execute the appropriate evasive maneuver without aid.

The findings which related to the conditions under which near inflight collisions occur agree substantially with an Air Force analysis of real collisions and with the data of the Naval Aviation Safety Center.

Insofar as collisions and near collisions may occur in related circumstances, one may conclude that accidents are likely to occur under optimum flying conditions. Whether this is a function of pilot overconfidence, traffic density, distraction or some other factor or combination of factors remains an open question. At any rate, the pilots were unlike the "Sunday driver" in that very few attempted to blame the other fellow for the hazardous circumstance. The occasional exception showed paternal condescension toward the civilian "Sunday pilot" who "clutters up the air space" with apparent lack of concern for other aircraft.

Maintainability of Fluorescent Paint

Since many pilots noted the problem of maintainability as being their only criticism of fluorescent paints, it seemed useful to obtain first hand opinion on fluorescent paint maintainability. Accordingly, the squadron maintenance officer and paint shop foreman of the squadrons visited were interviewed, where possible, regarding their experience with the paint.

Typically, the maintenance officers noted the more severe fluorescent paint application requirements. However, they also seemed to feel that, at least for shore based paint installations, fluorescent paint application represents no insoluable problems for the conscientious worker.

The need for more frequent repainting, when fluorescent paint is involved, was also mentioned. Doubt existed (and actual tests of paint durability are beyond the scope of the current program) as to whether fluorescent paint, when correctly applied, is actually less durable than ordinary paint or whether chips and soiled spots are merely more conspicuous with fluorescent paints.

The feeling tone of the squadron maintenance officers was generally that the maintenance problems associated with fluorescent paint have been exaggerated and that for shore applications in the words of one maintenance officer, "a high viz paint job which will last from 12 to 18 months is possible."

CHAPTER III

SUMMARY OF RECENT RESEARCH AND RECOMMENDATIONS

Recent research on the use of fluorescent paints may be generally classified into attempts to provide information which will answer one or more of the following questions:

1. How do fluorescent pigments differ from non-fluorescent pigments in their effect on visual perception?

2. Are differences, if any, between fluorescent and ordinary paints noted in basic research approaches verifiable in and important to real life detection situations?

In the sections of this report which follow, certain available studies are discussed and related to each of the above questions. The allocation of a study most relevant to question 1 or question 2 was, in some cases, difficult. The criterion employed was the subjective impression of the present authors on whether the contribution was more basic than applied or *vice versa*. Authors cited and readers may disagree with the categorization of certain reports. We offer no defense for miscategorization other than that others who have tried such a task will know the difficulties involved.

Effect on Visual Perception

When white light falls on a non-fluorescent surface, certain components of the light are reflected and other components are absorbed and dissipated as heat or some other non-visible form of energy. Kazenas (1960), for one, depicts the effects of fluorescence:

> "What these substances are capable of doing is that of converting the shorter wave lengths of light--the blue end of the spectrum--into longer wave lengths

> of light--the yellow-red end of the spectrum. Daylight fluorescent pigments, besides having this property of red conversion by means of fluorescence, also reflect light in the yellow-red end of the spectrum. Since 50% or more of daylight is composed of the violet and blue-green portion of the spectrum, it is easy to see why the daylight fluorescent pigments have such exceptional brightness. The yellow or red light which they normally reflect is reinforced by a good deal more of yellow-red light converted from the blue by their property of fluorescence."

Following this explanation to its logical conclusion would cause one to infer that the perceived brightness of fluorescent paint is really an artifact of the "unnatural" supersaturation caused by the fluorescent pigment.

This line of thinking is supported by the work of Evans (1959). Working with Munsell hues in the 5R (red) plane, Evans found that by increasing the purity of the stimuli, a point could be reached at which the normal pigments took on apparent characteristics of fluorescent material. Evans suggested that this corresponding appearance phenomena be termed "fluorence" or "fluorent," to distinguish it from true fluorescence. Evans described the phenomena as follows:

> ...Above this threshold at either higher luminance or purity, it was found that the colors seen were in the surface mode of appearance but gave the impression normally associated with colors that are known to fluorence physically...fluorent colors of high luminance and purity had in all cases an extraordinary dazzling brilliance, which must be seen to be believed.

and

> ...fluorent perceptions do not necessarily require fluorescent specimens for their

production and the fluorescent specimens do not necessarily produce the fluorence impression.

On the question of the apparent brightness of fluorescent colors, Evans conjectured that there are in fact two types of brightness. One type, that specified by the Optical Society of America, is the psychological correlate of luminance. The other type is due to high purity. Evans supports the argument for this second type of brightness because "colors at high purity appeared so bright compared to the surround as to be uncomfortable." The apparent brightness of fluorescent paint is possibly explainable, according to Evans, as due to the excess stimulation of a color receptor above its adaptation level.

The Applied Psychological Services in collaboration with the Air Crew Equipment Laboratory of the Naval Air Material Center has performed a number of comparisons of fluorescent and ordinary paints when hue and saturation are equated. By successively inserting neutral density filters in front of a yellow-orange fluorescent sample, a comparison stimulus was derived which subjectively matched the fluorescent yellow-orange in hue and saturation. This comparison stimulus (called "ordinary orange") was then used in a number of studies comparing reaction to various fluorescent, non-fluorescent, and achromatic stimuli.

In one study (Siegel and Crain, 1960), visual zonal limits measurements were made of fluorescent red-orange, fluorescent yellow-orange, fluorescent blue, ordinary red-orange, ordinary blue, and the ordinary orange comparison stimulus described above. Two zonal limits were measured: (1) the point at which the stimulus was first seen as a grey object, as it was brought in from the periphery ("outside limit"), and (2) the point at which the true color of the test object could be identified ("inside limits"). It was found that the fluorescent colors yielded larger average outside and inside limits than their non-fluorescent counterparts.

In a second study (Crain and Siegel, 1960), tachistoscopic thresholds were obtained for the same stimuli. Under each of two luminance levels, two thresholds were determined: (1) the point at which the stimuli could first be identified as objects, regardless of whether or not the color was identifiable, and (2) the point at which the color of the stimuli could be reported.

The fastest object recognition thresholds, for both luminance levels, were found in ordinary blue, ordinary red-orange, ordinary yellow-orange, and fluorescent blue. There was no statistically significant difference within this group. The color thresholds for the fluorescent paintr were generally lower (faster) than for the ordinary paints.

Then using only the comparison orange and fluorescent yellow-orange, an experiment was performed to determine the effects on the tachistoscopic threshold (Siegel and Crain, 1961) of varying stimulus shape, white space between colored areas, and filling stimulus gaps with blue. Again the comparison ordinary orange was found to possess a lower object threshold than the fluorescent orange. Adding a blue component and holding area constant lowered the threshold significantly further. Closing the separation between the chromatic areas or making the stimuli rectangular increased stimulus effectiveness.

Another related study (Blackwell, 1960), investigated the development of a technique for predicting the visibility of outdoor objects. The method attempts to extend previous visibility prediction nomographs by considering chromatic contrast. This consideration, which is important in fluorescent paints due to their increased chromaticity, was not included in previous visibility predictive work because a general understanding of the role of chromatic contrast is lacking. Essentially, Blackwell derived a conspicuity factor which for a given chromatic sample might take account of the chromatic contrast a sample provides in typical outdoor environments in addition to considering luminous reflectance, illumination, and background luminance. Blackwell maintains as the results of his work that "there is clear evidence that the chromatic samples are more visible than we would expect on the basis of reflectance alone." Although the values actually reported for fluorescent yellow-orange and international orange were nearly identical, he further suggests the following average conspicuity factor hierarchical rank: (1) fluorescent red-orange, (2) fluorescent yellow-orange, (3) international orange.

Verification in Field and Other Studies

The reports cited above lend support to a contention that fluorescent pigments would be expected to be more conspicuous than ordinary pigments. This could be a function of greater chromaticity, greater luminance, or some combination of the two. Whether the added chromaticity makes a difference in the bare detectability situation is open to question since at long distances all colors are first seen as "grey." It would be expected, as was found (Siegel and Crain, 1960), that fluorescent pigments due to their increased saturation would become apparent as colors earlier than non-fluorescent pigments.

Applied Studies

While not all applied studies have supported extrapolations from the more basic studies, a large number of the applied studies have produced results in the expected direction. Two field visual range detectability studies have resulted from the colloborative Applied Psychological Services-Air Crew Equipment Laboratory program (Siegel, 1961; Federman and Siegel, 1962). These studies demonstrated marked changes in the rank order of detectability produced by various stimuli with varying sun positions and sky background conditions. On the whole and across sun positions and background conditions, the following rank order of detectability seems to be the best estimate of the detectability of the stimulus combinations tested by that program's visual range technique:

Stimulus	Rank (object and color threshold)
Fluorescent yellow-orange	1
Fluorescent red-orange	2
White	3
White with a fluorescent red-orange stripe	4
White with a black stripe	5
Comparison orange	6

In a detectability study performed under slightly different circumstances, the Naval Medical Research Laboratory (1955) compared through air to sea sightings, targets coated with 16 ordinary paints of varying brightness and saturations in the yellow through red range, black and white, white, and four fluorescent paints. Against the sea background, colors which were detected at the greatest distances were the yellow-red and orange-red fluorescents; next in detectability were the ordinary paints of high brightness and/or saturation. White, a color which has been shown to possess good detectability in other studies, was reported as possessing marked variability.

Richards, Woolner, and Panjiam (no date) compared the conspicuity of fluorescent pigments, ordinary pigments, and white when a New England tree (evergreens and hardwood in October, November, and January) background was involved. These investigations concluded that a "daylight fluorescent orange" was the most conspicuous. Accordingly, daylight fluorescent orange with a dominant wave length between .595 and .605 μ, a luminance factor of not less than 50 per cent, and a purity of not less than 90 per cent was recommended for consideration by the Legislature of Massachusetts for inclusion in the hunting law.

In 1959 the Federal Aviation Agency established a program which, amongst other considerations, was to study the influence of paints on aircraft detectability, conspicuity, and collision avoidance. The results generally supported the employment of standardized paint schemes including the use of some fluorescent coating.

One of the forerunners of the current family of tests employing models and simulated sky background was a study of the Air Crew Equipment Laboratory (Wagner and Blasdel, 1948). In this study a series of paint patterns and backgrounds was employed. The results indicated a glossy sea blue and aluminum combination to yield the highest criterion score (heading accuracy judgment).

A study of Anders and Lenz (1957) indicated a combination of white, black, and fluorescent orange most useful for identifying airdrop targets and Fitzpatrick and Wilcox (1960), employing a variety of natural backgrounds found fluorescent yellow-orange to possess superior recognition value to international orange, yellow, and white. For detection no single stimulus was found superior.

Skeen (1958) and Baker (1960) indicated no significant increase in distance detectability for fluorescent painted aircraft but an increase in conspicuity for these aircraft at nearer distances. Similarly, an FAA sponsored study as reported by the Applied Psychology Corporation (1961) indicated no substantial detectability advantage for fluorescent paints. In contrast, a Coast Guard study indicated the use of dark aircraft undersurface, light uppersurfaces, and fluorescent red or orange on large areas.

In summary, it seems that the extrapolations and predictions from the laboratory have been largely substantiated in the field studies. This does not indicate however that additional laboratory and field studies are not required. A number of gaps exist in our knowledge of fluorescent paint. Moreover, at least one study (Marshal, 1962) failed to confirm superiority for fluorescent paints over ordinary paints when actually moving aircraft targets were employed. Thus it seems that the results of this FAA study should be checked in the laboratory with targets employing the same angular acceleration as an aircraft flying at given speeds and distances. If the FAA finding is contraindicated in the laboratory, then a repetition of their field study would also be required.

Few, if any, of the applied studies have required the subjects to scan a horizon. Rather the studies have asked the viewers to state whether a target was present within a given field. The question of whether the same results and indications would be obtained if the experimental subjects were required to scan a horizon for the stimuli remains open and should be investigated.

The psychological effects of fluorescence on operator work efficiency should be investigated in order to determine whether any increment in detectability or conspicuity is accompanied by disadvantageous side effects. Similarly and in view of pilot reports on depth perception debilitation when fluorescent paints are employed, immediate laboratory study of this possibility seems indicated. Confirmation of these reports would have serious implications on the use of fluorescent paint when formation flight, in-flight refueling, and other close proximity situations are involved.

The short range conspicuity advantage, if any, of fluorescent paint has not been systematically investigated. At long detection ranges, atmospheric attentuation may be expected to mitigate the effects of chromatic contrast. However, at short and moderate ranges, the increased chromatic contrast of fluorescent paint may be expected to add a conspicuity advantage. Field studies should be performed to check this extrapolation.

The recommendations of the FAA sponsored studies should be carefully cross-checked by an agency other than that which performed the first studies. In these checks, the methodological errors inherent in the FAA sponsored work should be corrected.

The Optimum Paint Question

Should fluorescent pigments be used on aircraft exteriors?

> First, it seems that few, if any, studies have indicated fluorescent paint to be inferior, from the conspicuity point of view, to other colors and to achromatic stimuli. Under certain conditions, achromatic stimuli (white and black) can be expected to yield greater distance detectability than the fluorescent paints. However, under a number of conditions the detectability of fluorescent paint is almost equivalent to and in some conditions its detectability is superior to the achromatic stimuli. Generally, little, if any, loss in detectability can be expected from the use of fluorescent pigments and considerable gain in conspicuity can be anticipated. Further contentions in support of the use of fluorescent paint are its suggested greater peripheral visual detectability, its low tachistoscopic threshold, and the chromaticity it affords, Additionally, the interview study indicated that, at least for the Navy, pilots <u>think</u> that fluorescent paints help. This safety reassurance, providing it doesn't yield a false sense of security, seems worthwhile.

If fluorescent pigments are useful, what fluorescent pattern should be used?

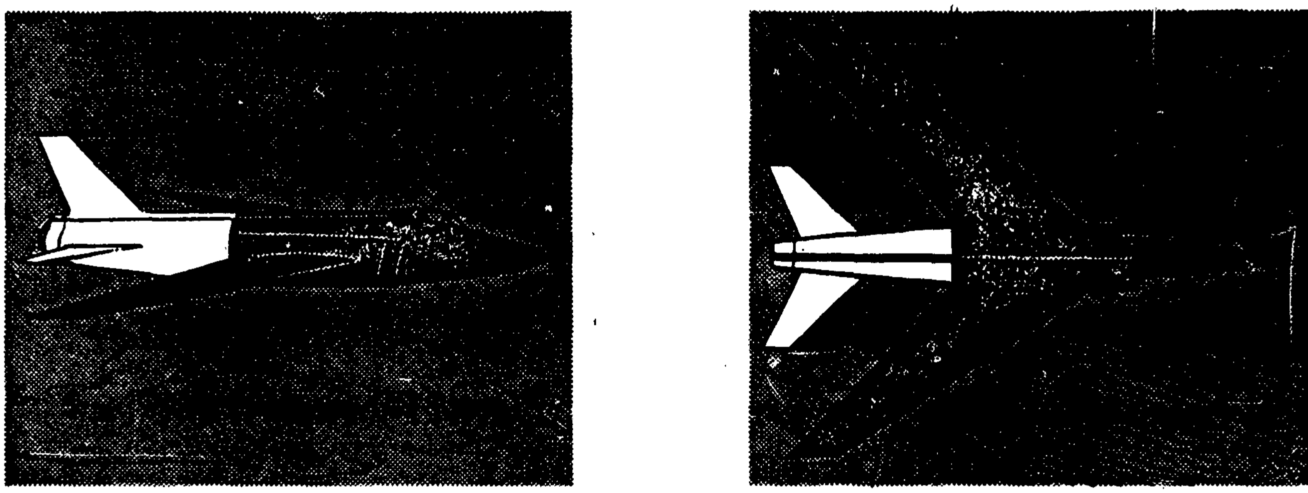
> A number of studies have shown that the utility of fluorescent paint increases with its area of coverage. Moreover, it has been indicated that the fluorescent area should be unbroken and preferably squarelike. Thus large, unbroken fluorescent areas can be expected to

yield maximum effectiveness.

Should the fluorescent paint be used in combination with a second stimulus?

> Under certain conditions, achromatic stimuli can be expected to yield increased detectability. A tachistoscopic study of Crain and Siegel (1960), indicated that addition of blue to a fluorescent stimulus lowered the recognition threshold of the stimulus. White or glossy sea blue seem to be preferable for use in combination with the fluorescent red-orange or orange-red. Increased detectability can be expected to emerge from the combination due to the increased internal and external contrast afforded by the second color. The choice between white and sea blue in combination with the fluorescent pigment demands empirical research investigation. However, glossy sea blue (paint #623) possess a low reflectance (0.58%) and should provide high <u>internal</u> brightness contrast with the fluorescent pigment. Additionally, since glossy sea blue and fluorescent red-orange are at opposite ends of the reflectance continuum, maximum external contrast would then be afforded against any background. Moreover, these colors are at different ends of the color spectrum and should provide good color contrast. The use of glossy sea blue is also supported by results of the study of Wagner and Blasdel (1948).

One schema, based on the above recommendations, is shown in Figure 1. Employment of this or any paint scheme would of course be weighed in the practical situation against factors such as the inability to employ certain paints on heat areas and control areas.



Fluorescent red-orange

Glossy sea blue

POSSIBLE HIGH VISIBILITY PAINT SCHEME

Figure 1

It will be noted that the schema portrayed in Figure 1 is at variance with the currently suggested FAA paint scheme (Klass, 1962) which involves painting the underside of the aircraft dark, the topside a light color, and the empennage fluorescent orange-red. This FAA recommendation seems to provide good internal and external brightness contrast as well as some color contrast. Several questions remain open, however, in regard to the FAA scheme. For example, the minimum area application of fluorescent paint seems to mitigate any effectiveness that might be expected from its employment. Moreover, reports of the contractor who performed the research behind the FAA paint scheme stated (Cook and Robinson, 1962):

> ...Specifically, the row totals show that there was no meaningful difference between the solid-grey models and the models with a differential brightness treatment on top and bottom

and (Applied Psychology Corporation, 1961):

> ...Maximum brightness contrast areas within different portions of the aircraft's surfaces does not lead to enhanced conspicuity

The recommendation of the FAA contractor seems principally supported by the purported lower variance of the visibility of the suggested pattern. In the words of the contractor (Applied Psychology Corporation, 1961):

> ...First, all of the paint patterns held an advantage over the unpainted aluminum model. Second, although there was no clearly superior pattern, the pattern with the top and bottom differentiated (white-and-grey), and only the empennage painted (small fluorescent area) yielded some favorable results. Figure 5 shows that the other patterns either had a greater spread of mean scores, or lower actual mean

> scores, with respect to the four backgrounds. This may be interpreted as an indication of unreliability of these patterns. On the other hand the pattern mentioned above yielded generally high mean scores that did not exhibit much spread. It thus might be presumed to be relatively consistent against a variety of backgrounds.

The test data referred to by this statement were taken in a static test situation in which models, viewed against artificial backgrounds were used as test stimuli. None of the data were taken at or near the thresholds of visibility. The scores referred to are aircraft attitude judgments, not visibility scores. While the contractor's statement appears to be supported by his Figure 5, it is noted that no standard statistical test was performed for differences between variances.

Accordingly, additional studies seem required into the FAA supported paint pattern and further comparison between it and other suggested schemes (such as that outlined above, current Naval schemes, etc.) are needed.

Finally, it is noted that the fluorescent and white pattern currently employed by the Navy finds much support in the laboratory and field studies noted throughout this report.

CHAPTER IV

SUMMARY AND CONCLUSIONS

A group of 96 pilots representing a variety of Naval squadrons were interviewed in order to obtain their points of view toward the application of fluorescent paint and insights into the conditions under which near mid-air collisions and possibly actual collisions occur. The near miss data obtained, which agreed for the most part with other similar analyses and with certain analyses of real mid-air collisions, suggested that the typical collision precursory situation is during daylight under near optimum visual conditions, below an altitude of 10, 000 feet, in an airport control area or during level flight. Most pilots chose the "airport control area" (as contrasted with the cruise phase) as most important for quickly determining the presence of an intruding aircraft. Opinion was almost evenly divided as to whether from the same point of view, take-off and climb-out is more important than landing; similar split results were obtained from a comparison of "cruise" with "holding patterns."

The data suggested that the pilots believed high visibility pigments should be used for increasing aircraft conspicuity and detectability, rather than for various coding and identificatory purposes. Once having perceived the intruding aircraft, the pilots considered themselves capable of initiating the appropriate evasive action without accessory collision avoidance information which might be delivered through the employment of various external coloration schemes.

The pilots strongly favored fluorescent paint from the detectability and conspicuity points of view and many could cite examples of situations in which the fluorescent paint helped them to detect an aircraft which they might not have otherwise seen. Typically, although the maintainability of fluorescent paint was questioned, the more experience a pilot possessed with high visibility paint schemes, the more he accepted its use.

A review of recent basic studies on the use and application of fluorescent paint indicated that generally fluorescent pigments have been found to be more conspicuious than ordinary pigments. This added conspicuity could be a function of greater chromaticity, greater luminance, or some combination of the two. No clear indication was given as to whether greater detectability can be expected from fluorescent paints, although it was pointed out that fluorescent pigments due to their increased saturation could be expected to become apparent as colors earlier than non-fluorescent pigments.

Although extrapolations from the basic studies have been generally confirmed in the more applied, field tests, exceptions have been noted. Some of these exceptions are possibly explainable on the basis of the different methodology employed in the two types of studies. However, additional field tests are needed, especially concerning conspicuity at intermediate ranges and detectability under dynamic conditions. A number of basic studies were also indicated into fluorescent pigments. Particulary worrisome is pilot reports of disturbed depth perception when fluorescent pigments are involved.

The authors considered that in the current state of the knowledge, fluorescent paints may help (and certainly not harm) mid-air collision avoidance. The fluorescent application suggested was unbroken and as squarelike as possible. A second contrasting color (glossy sea blue) was suggested for use in combination with fluorescent red-orange or orange-red.

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APPENDIX A

Appendix A presents the schedule employed in the interview study reported in Chapter II.

Interviewer ______________________________

1. Have you, in your operational experience, ever experienced a near in-flight collision during daylight? (If no, ask, what is the closest you ever came to such a condition?)

   Under what conditions did it occur?

   altitude
   visibility
   relative speeds
   activity
   flight phase
   sun position
   sky background
   aircraft types
   time
   type of clearance

   Will you draw me a diagram of the flight paths involved?

   How far were you from the intruding aircraft when you first saw it?

   What was the miss distance?

   Did either aircraft contain high visibility (fluorescent) marking?

   Were you wearing sun glasses at the time?

2. Research has suggested that it is not possible to paint an aircraft so that it will be maximally visible under all conditions. For example, that paint scheme which will make an aircraft most visible under low visibility conditions may not be superior, from the detectability point of view, against a bright, white cloud sky background.

   In your experience have you found it more important to quickly determine the presence of an intruding aircraft:

   a.____ in an airport control area or

   b.____ in cruise

DIAGRAM

How so? ______________________________

____

____

a. _____ during take-off and climb-out or

b. _____ during landing

How so? ______________________________

____

____

a. _____ in a holding pattern or

b. _____ during cruise

How so? ______________________________

____

____

a. _____ below 10, 000 feet

b. _____ between 10, 000 and 20, 000 feet

c. _____ over 20, 000 feet

How so? ______________________________

____

____

3. It is possible to use colors for aircraft coding purposes or for increasing aircraft visibility and detectability. Which is more important?

a. ____ coding or

b. ____ detectability

How so? ______________________________

____

____

4. If you had the choice of seeing an intruding aircraft early but less clearly as opposed to later but more clearly when it became apparent, which would you take?

a. ____ early but less clearly or

b. ____ later but more clearly

How so? ______________________________

____

____

5. It is possible to code aircraft exteriors in various ways through paint schemes. For example, paint schemes could be used to denote the relative altitude of an intruding aircraft but you would not be able to detect the intruding aircraft at as great a distance.

a. Would you prefer visual information on relative altitude even at the expense (trade-off) of distance detectability? ____ yes ____ no.

If yes, why so? ______________________

____

____

b. Would you prefer a paint scheme which told you the relative flight path of an intruding aircraft, even at a considerable loss of distance detectability? ____yes ____no.

If yes, why so? ____________________

____

____

____

c. Would you prefer a paint scheme which told you something about the relative distance of an intruding aircraft, even at the loss of detectability? ____yes ____no.

If yes, why so? ____________________

____

____

____

6. (Show card) Which, if any, of the following codings do you think you would like to see incorporated into aircraft paint schemes. ____rel. speed ____rel. alt. ____rel. direction ____rel. distance.

Of those you have selected arrange them in their order of importance to you.

7. I suppose that you have seen fluorescent paints such as this (show sample) around airports and in flight. What do you think of it? ____________________

____

____

____

What do you like best about it? ________

____

____

____

Least? ________________________

____

____

____

8. Can you think of any situation in which it has helped you to detect the presence of an aircraft which you might not have seen otherwise? ____yes ____no

(If yes) Tell me how the fluorescent paint helped. ________________________

____

____

____

9. Can you think of any situation in which it has hindered you, distracted you, or has given you wrong or distorted information? ____yes ____no.

(If yes) Tell me how the fluorescent paint hindered you or gave you wrong or distorted information. ____________

____

____

____

10. Has your impression of the usefulness of fluorescent paint for aircraft detectability purposes changed from when you first became aware of its usefulness for this purpose? ____yes ____no.

If yes, how? ______________________________

____

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Name ______________________________ Rank ____________ Date __________

Location ______________________________ Flight Hours ______________

prepared by

Applied Psychological Services
Wayne, Pennsylvania

NAVAL AIR ENGINEERING CENTER, PHILA. 12, PA.
AIR CREW EQUIPMENT LABORATORY

1. Report NAEC-ACEL-492
WEPTASK RRMA 05 078/200 1/F012 16 003

EVALUATION OF HIGH-VISIBILITY, COLOR SCHEMES FOR AIRBORNE VEHICLES

Aircraft Detectability and Visibility: VI. A Qualitative Review and Analysis of the Utility of Fluorescent Paint for Increasing Aircraft Detectability and Conspicuity; by A. I. Siegel and R. Lanterman, Applied Psychological Services, Wayne, Pa. NAVAIRENGCEN Contract N156-38581 - Collaborator, LT B. H. Lowi, 4 Mar 1963, 54 p.

Both pilot opinion and recent basic and applied studies of fluorescent paint are considered. The pilot opinion sampled supported the use of fluorescent paint for increasing aircraft conspicuity and detectability. Although not all the basic and applied studies of fluorescent paint reviewed indicated self-consistent findings, the use of fluorescent paint for increasing aircraft conspicuity and detectability also seemed indicated by these studies. A series of recommendations on fluorescent paint application is presented.

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